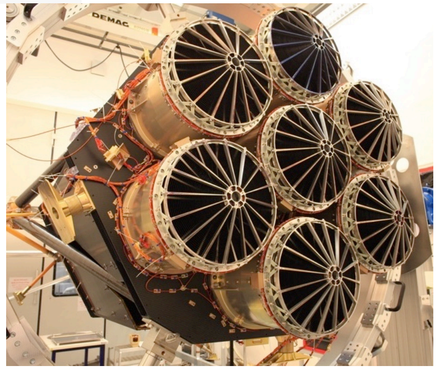
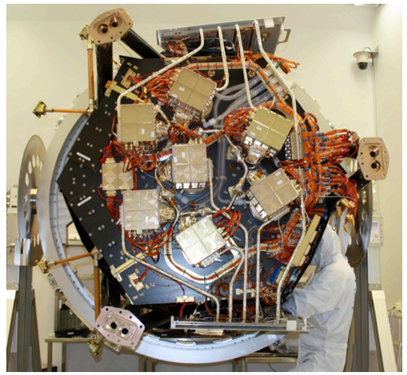
eROSITA insights on the hot and energetic Universe and Synergies with UVEX

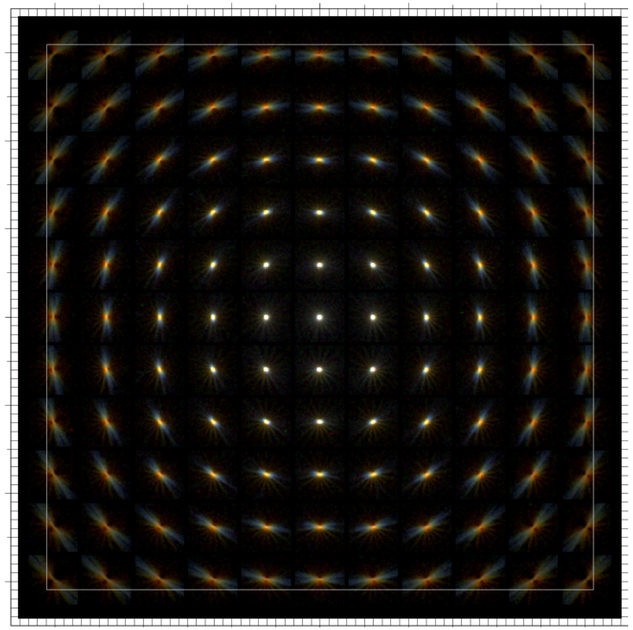
Mara Salvato (on behalf of eROSITA-DE)

eROSITA technicalities in one slide





Number of telescopes	7 w/ 54 mirror shells each
HEW on axis/survey	18”/30”
Energy range	0.2-10 keV
Spectral Energy Resolution	138 eV @ 6 keV (~XMM) 80ev@ 1.5 keV (R~20)
Focal Lenght	1.6 m
FoV	0.81 sqdeg
Effective Area	1700 cm^2



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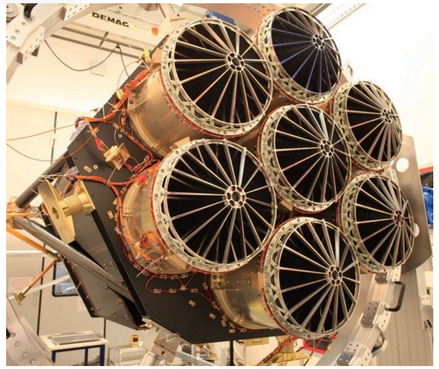

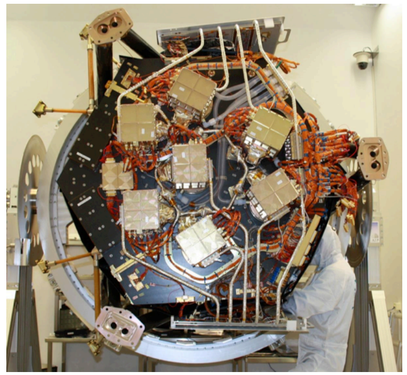

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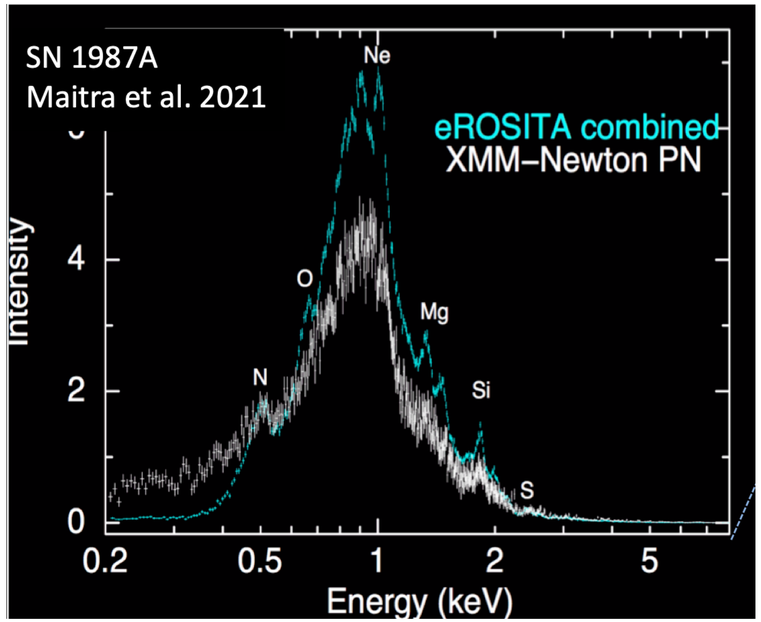
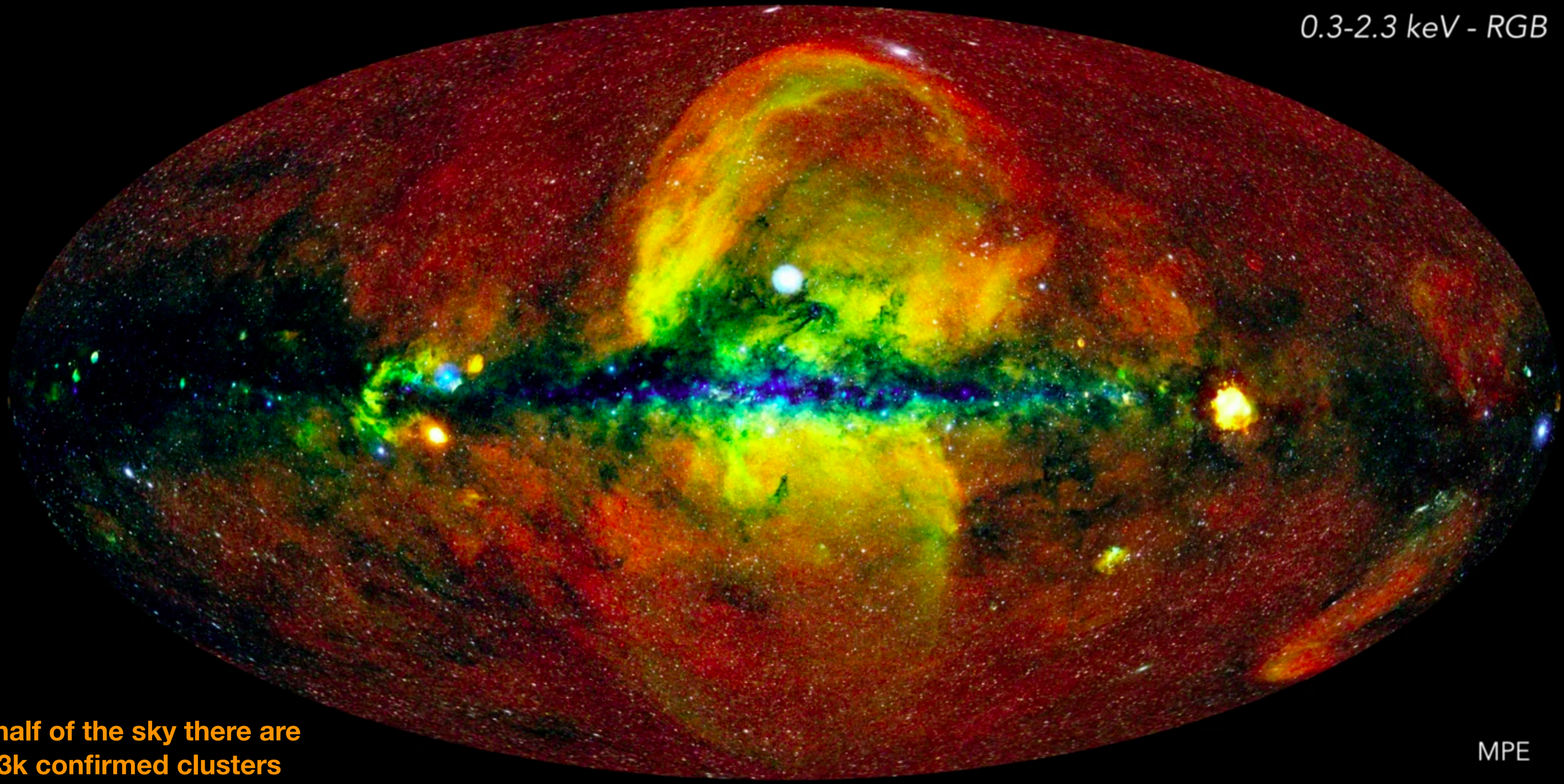


best CCD camera available in space
high spectral resolution (~100 eV)

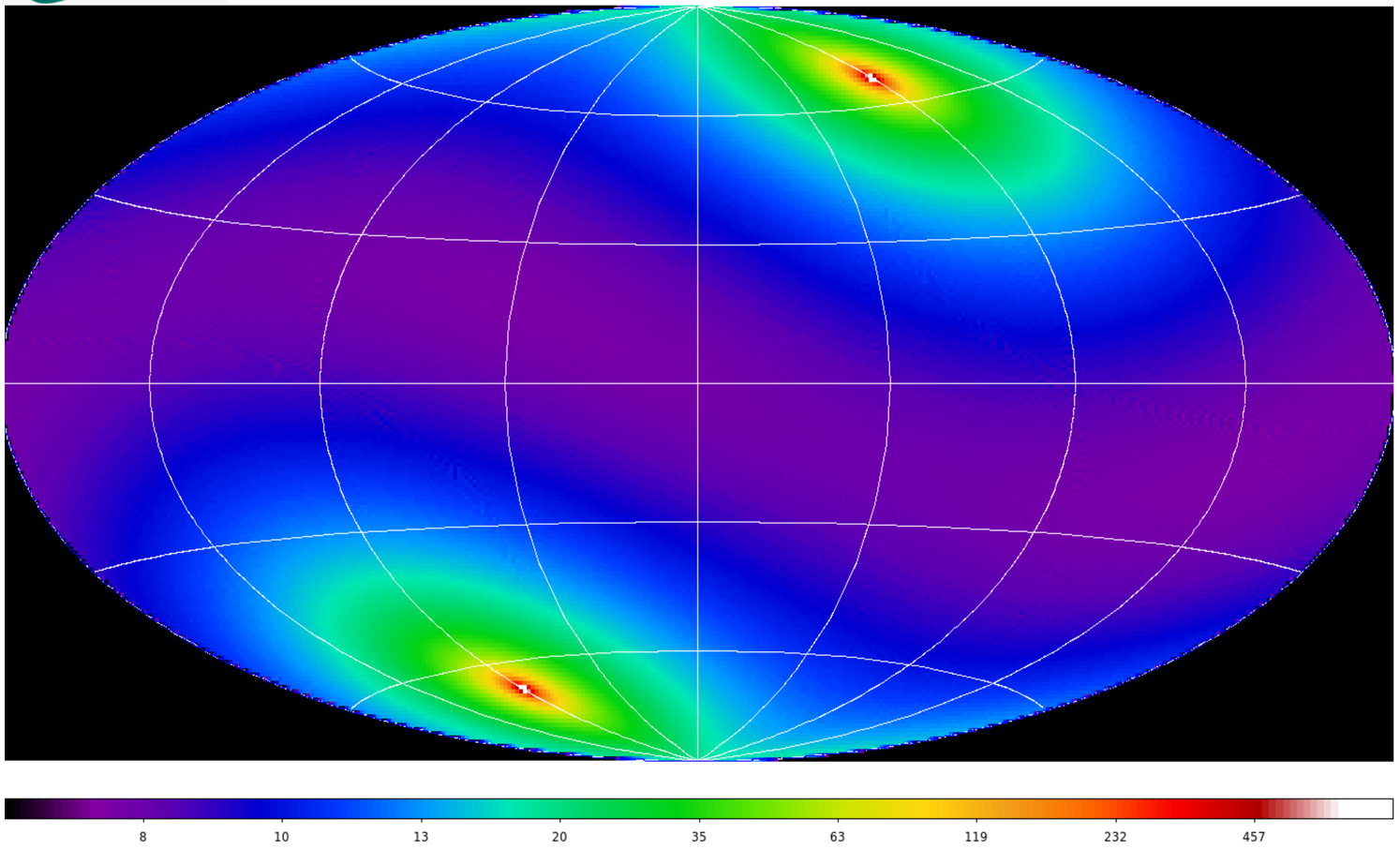
Stable &homogeneous background

The sky as seen by eROSITA in the first pass



in half of the sky there are
13k confirmed clusters
700k active SMBH (AGN)
140k coronal stars

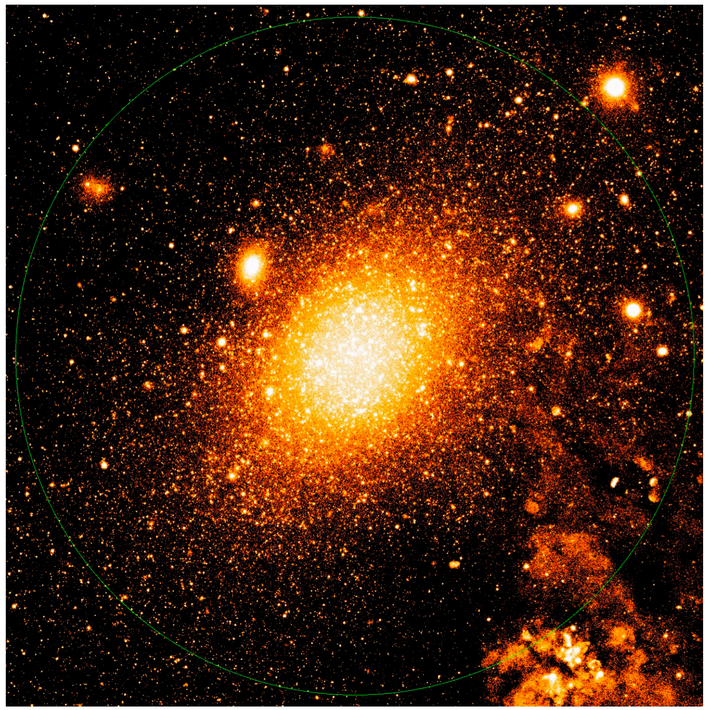
eROSITA Cadence Map



# of daily eROSITA visits over 4yrs

- 4 years: 8 all-sky surveys
- 6 months: one complete all-sky survey
- 4 hours: Rotation period of SRG (Interval between scans)
- 1 day: overlapping scans at ecliptic equator. Every day at the ecliptic poles

SEP in eRASS:4

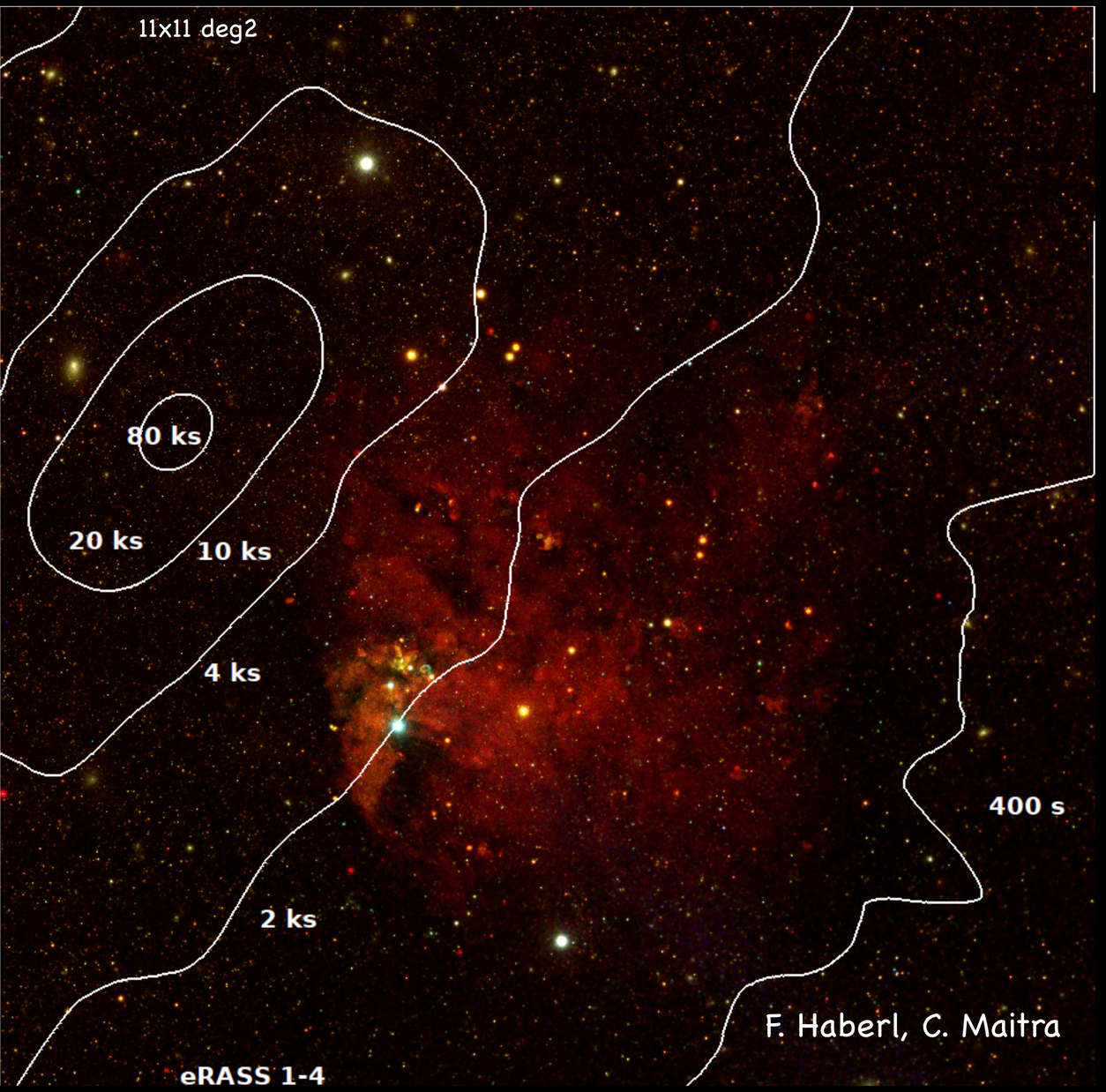


CREDIT: Teng Liu

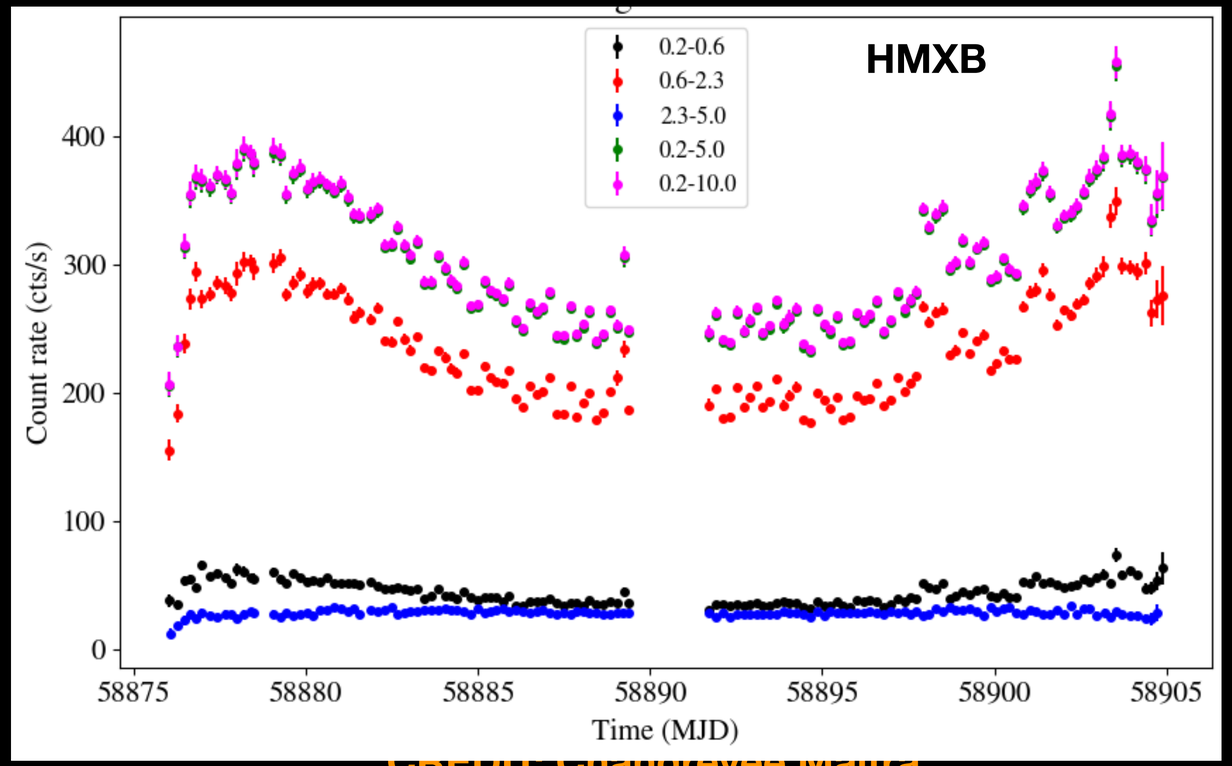
1 daily visit $F_{0.5\text{-}2} \sim 4 \times 10^{-14}$ erg/s/cm^2

$L_X > 10^{43}$ at D<1.5 Gpc (z~0.3); $L_X > 10^{44}$ at D<4.5 Gpc (z~0.7)

eROSITA in the MCs

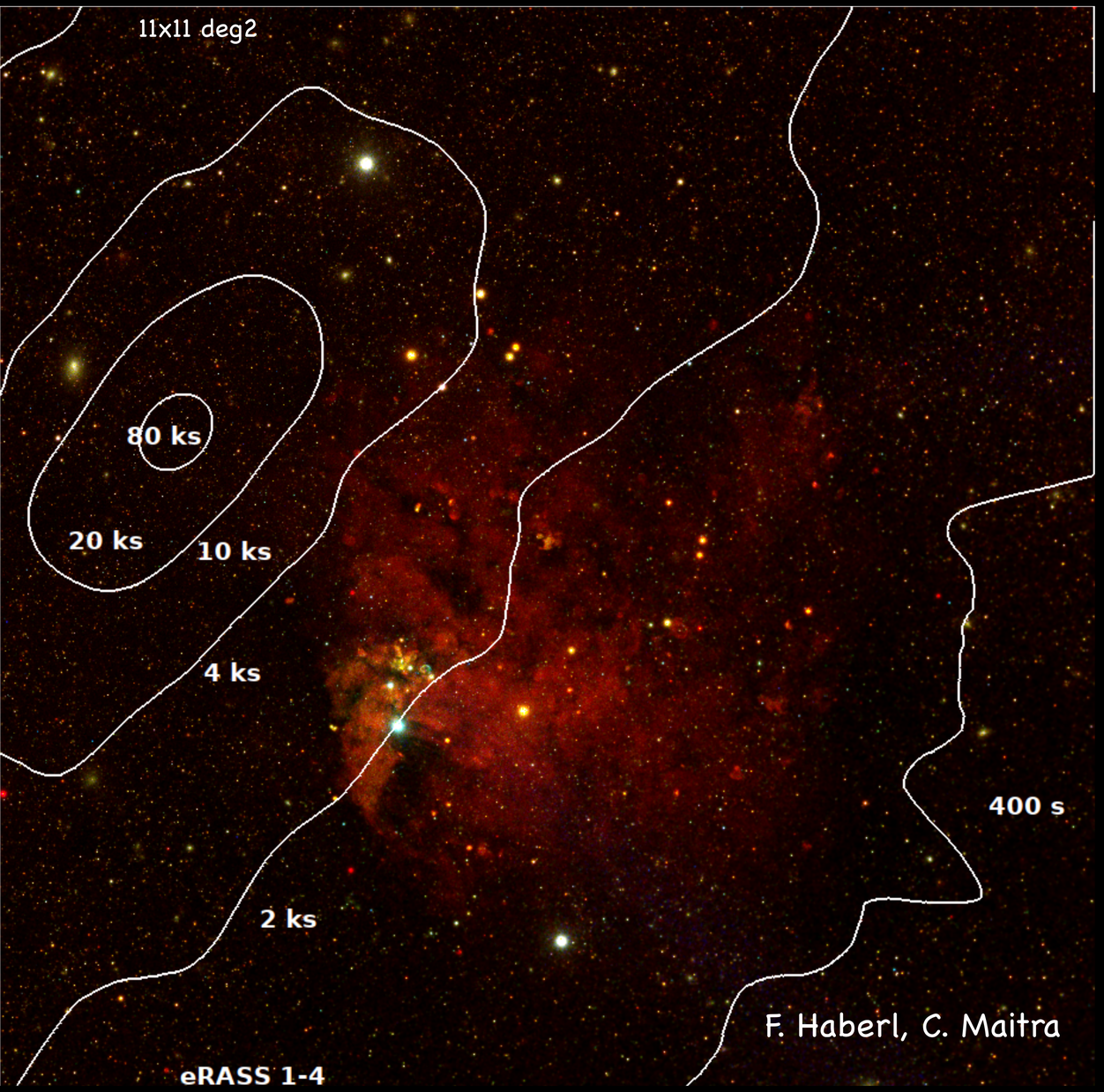


- complete eROSITA map of MCs down to Lx ~10^32 erg/s (8500 sources just on LMC)
- High cadence allows long X-ray variability studies of physics, stellar winds and accretion in massive stars
- study relation between HMXBs and SFH to understand the differences in the stellar content of the Clouds



CREDIT: Chandreyee Maitra

eROSITA in the MCs



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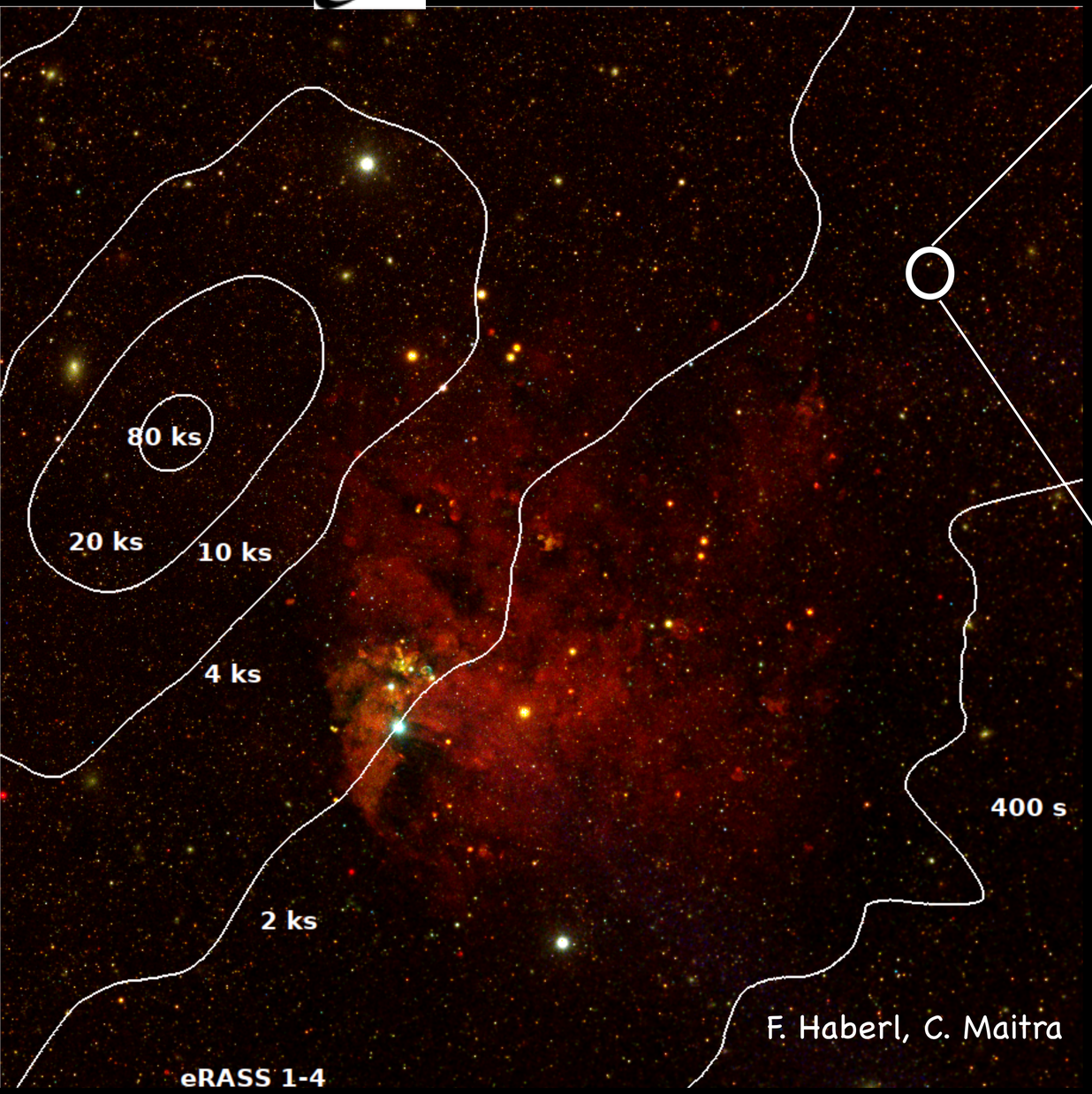
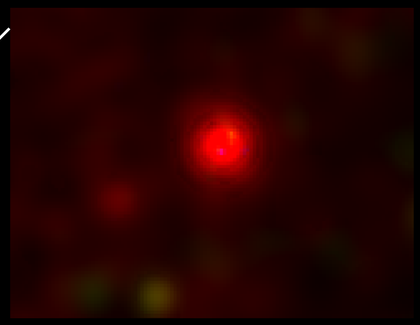
Synergy — UV + X-rays

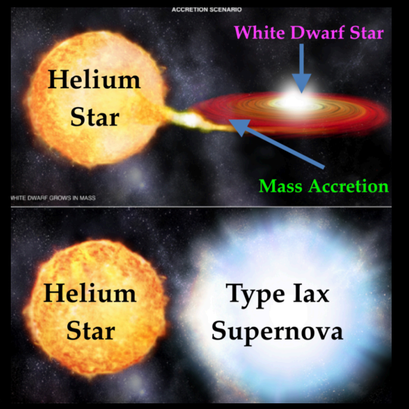
- Using high resolution UV and X-ray surveys to study the dust to gas ratio in the MCS
- Study stellar feedback and energy budget in the ISM from massive stars (especially in high stellar density regions like 30 Doradus)
- Map the star formation history and metallicity dependencies on the different population of XRBs in the MCS

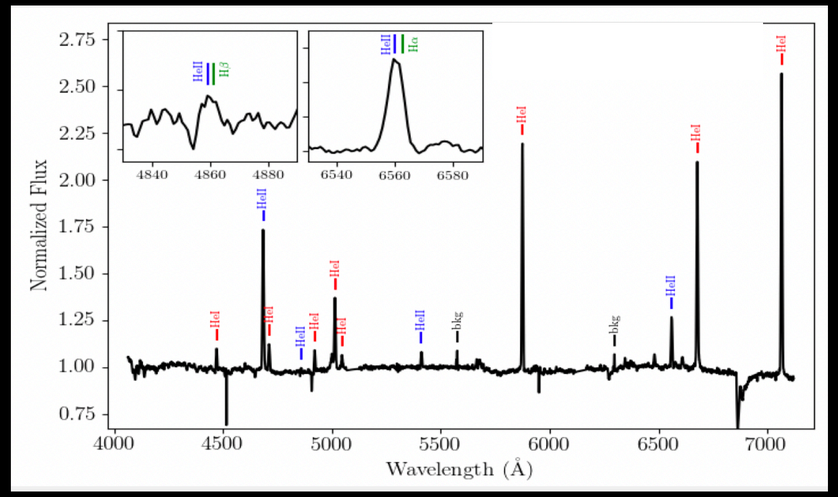
CREDIT: Chandreyee Maitra

Mapping the LMC eRASS:4









He accreting WD system as a SSS discovered in LMC
Greiner, Maitra, Haberl+23, Nature (in press)

Synergy — UV + x-rays

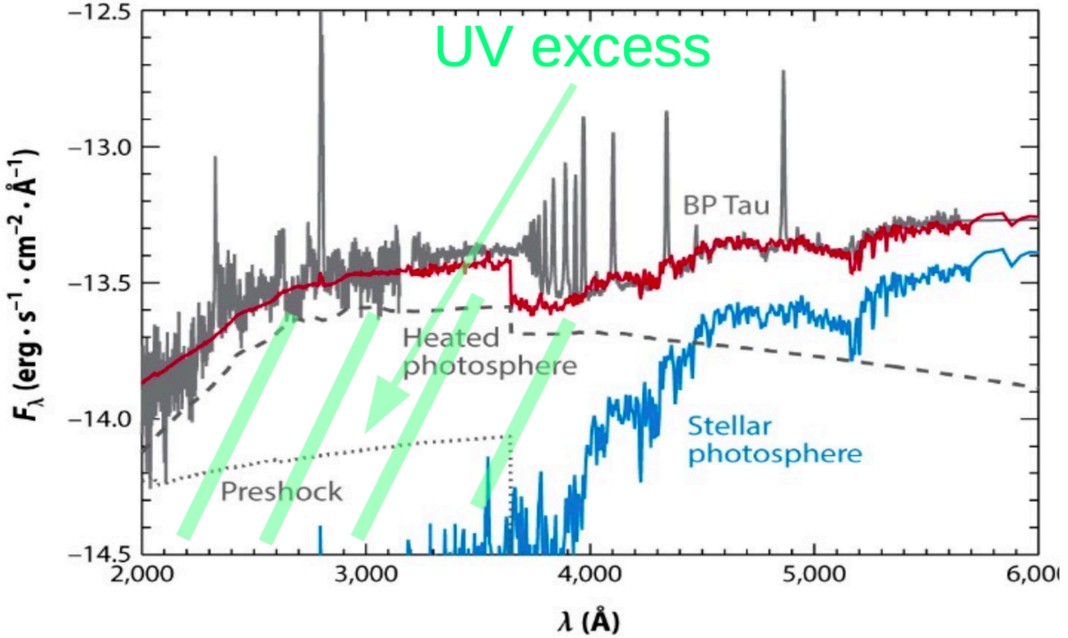
- Map the census of WR stars and colliding wind binaries in the MCS
- Study the progenitors of Type 1a SN — accreting WD
- UV can be used to search for ionised nebula in these objects and X-ray for the nuclear burning of the WD

CREDIT: Chandreyee Maitra

Synergies: young stars

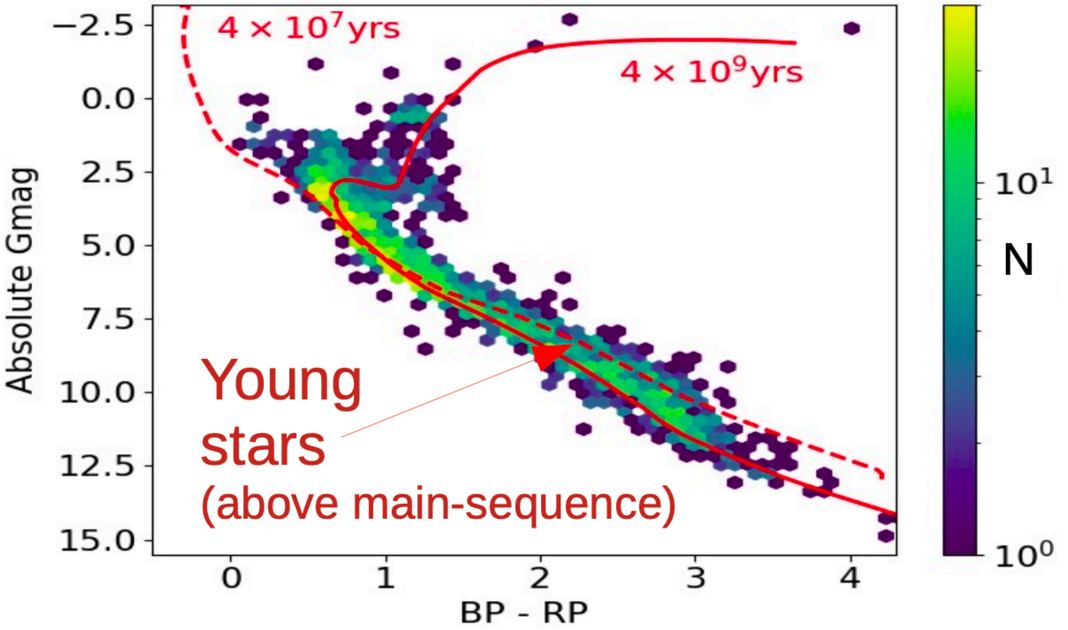
- Accreting stars show an **UV excess**
  brighter by ~1 dex in UVEX bands compared to non-accreting stars
- Young stars are also **X-ray bright**
  due to magnetic activity caused by fast rotation
- X-ray brightness (almost) independent of accretion
  Accreting stars are only slightly *fainter* in X-rays
- Young but non-accreting stars generally difficult to distinguish from field stars
- *Combining UVEX and eROSITA allows one to*
  - probe the complete young population
  - differentiate accreting from non-accreting stars
  - measure the time-scale for accretion*
  - measure the full high-energy SED*
  (*Important parameter for planet formation)

UVEX



From Hartmann et al. (2016)

eROSITA



From Schneider et al. (2022)

CREDIT: Christian Schneider

Synergies: magnetic activity

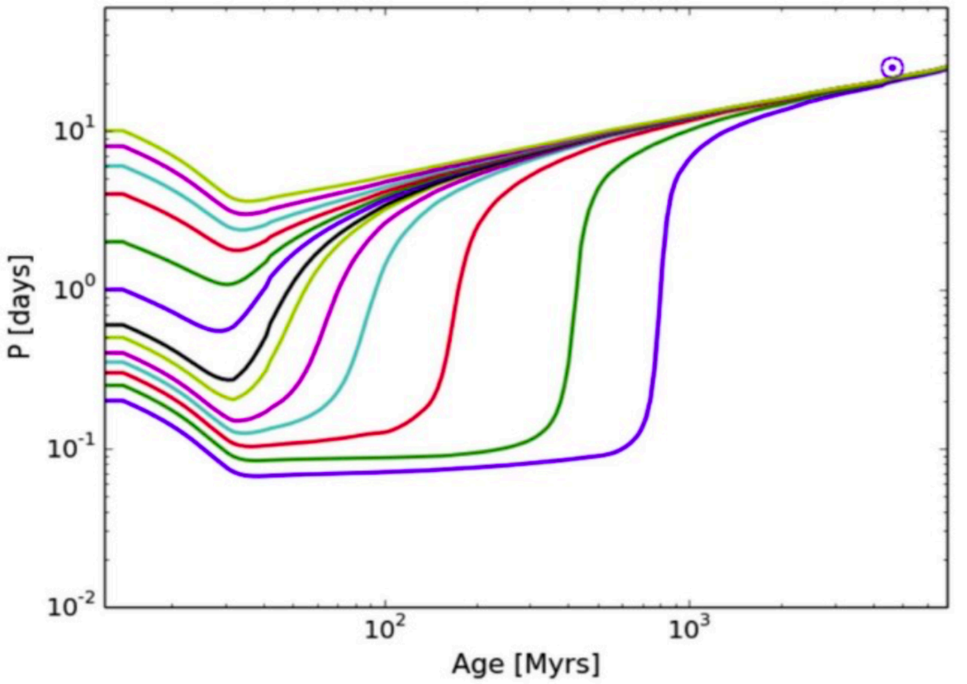
- Young stars generally have short rotation periods
  → Strong magn. dynamo
  → Angular momentum loss by magn. stellar winds
  → Spin-down with age

- X-ray and UV emission probe different regimes of magn. Activity
  X-rays: corona (10^6K), UV: transition region (TR, 10^5K)

- X-ray and UV emission decays differently with decreasing magn. Acitivity
  X-ray emission decays more quickly than UV emission

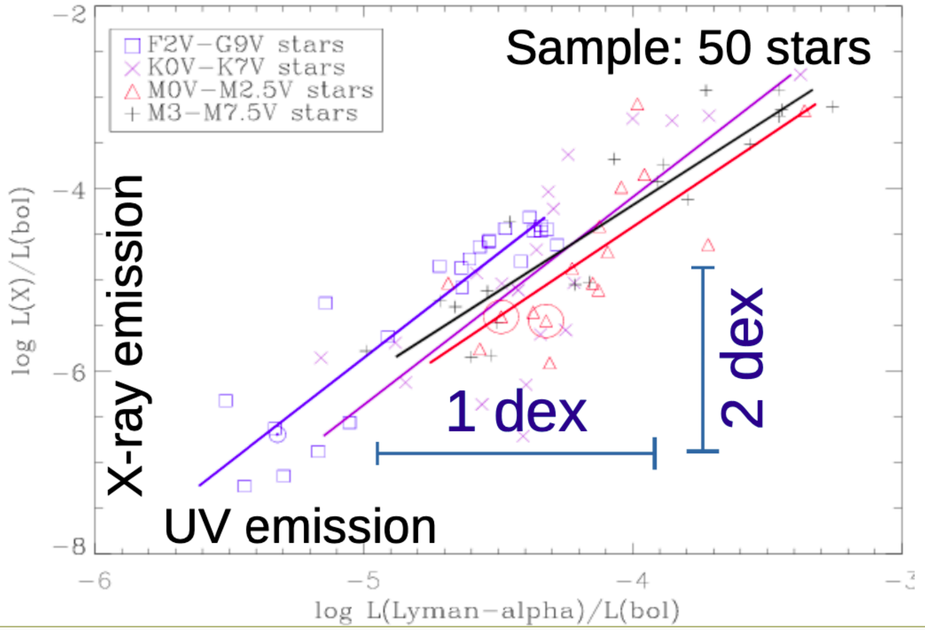
- *Combining UVEX and eROSITA allows one to*
  - probe the relative strength of corona and TR
    → heating of outer atmospheric layers
  - probe the underlying magn. dynamo
  - measure how planetary irradiation changes with time
    → affects exoplanetary population observed today

Rotation Evolution



From Garraffo et al. (2018)

UV + X-ray



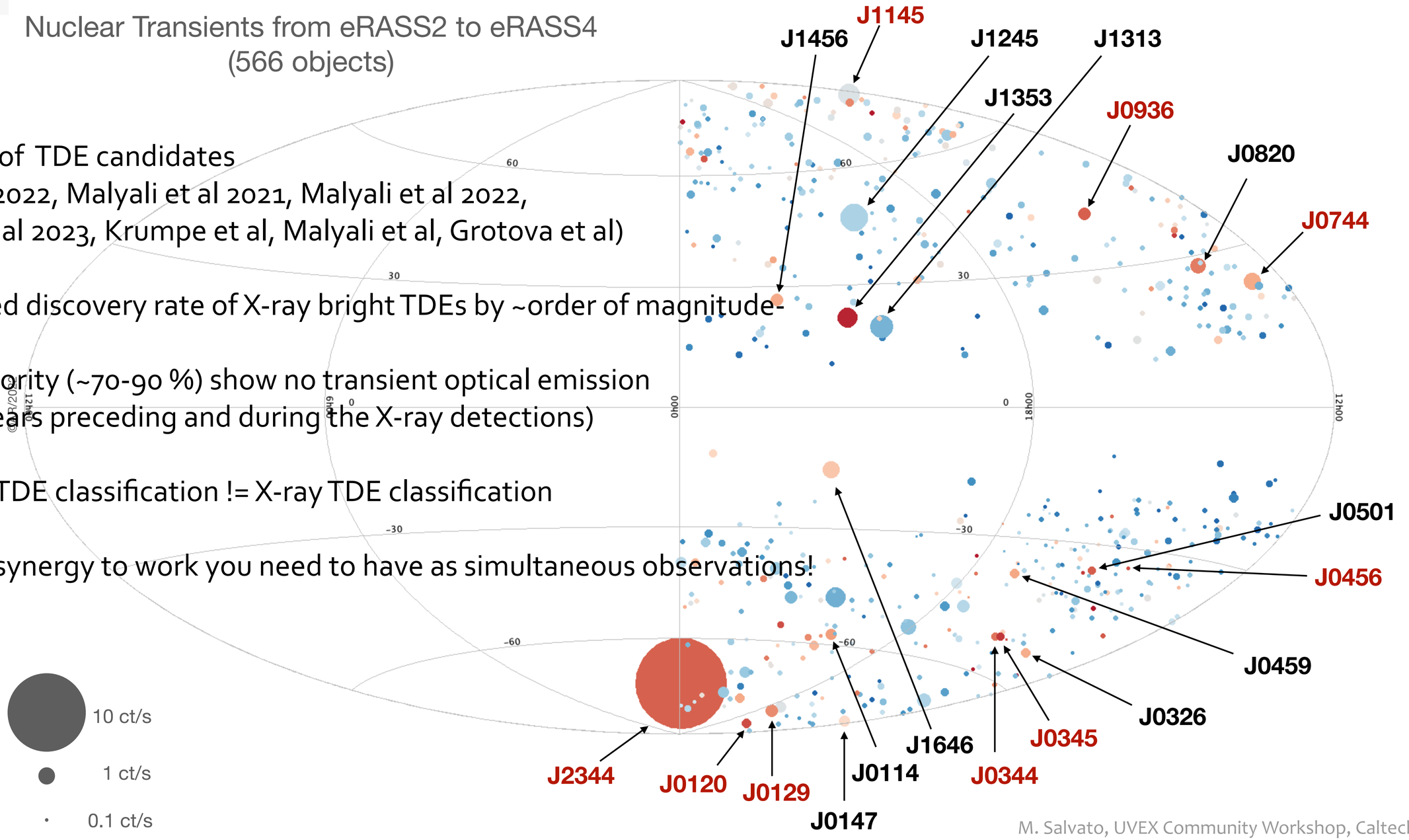
From Linsky et al. (2020)

(nuclear) transients

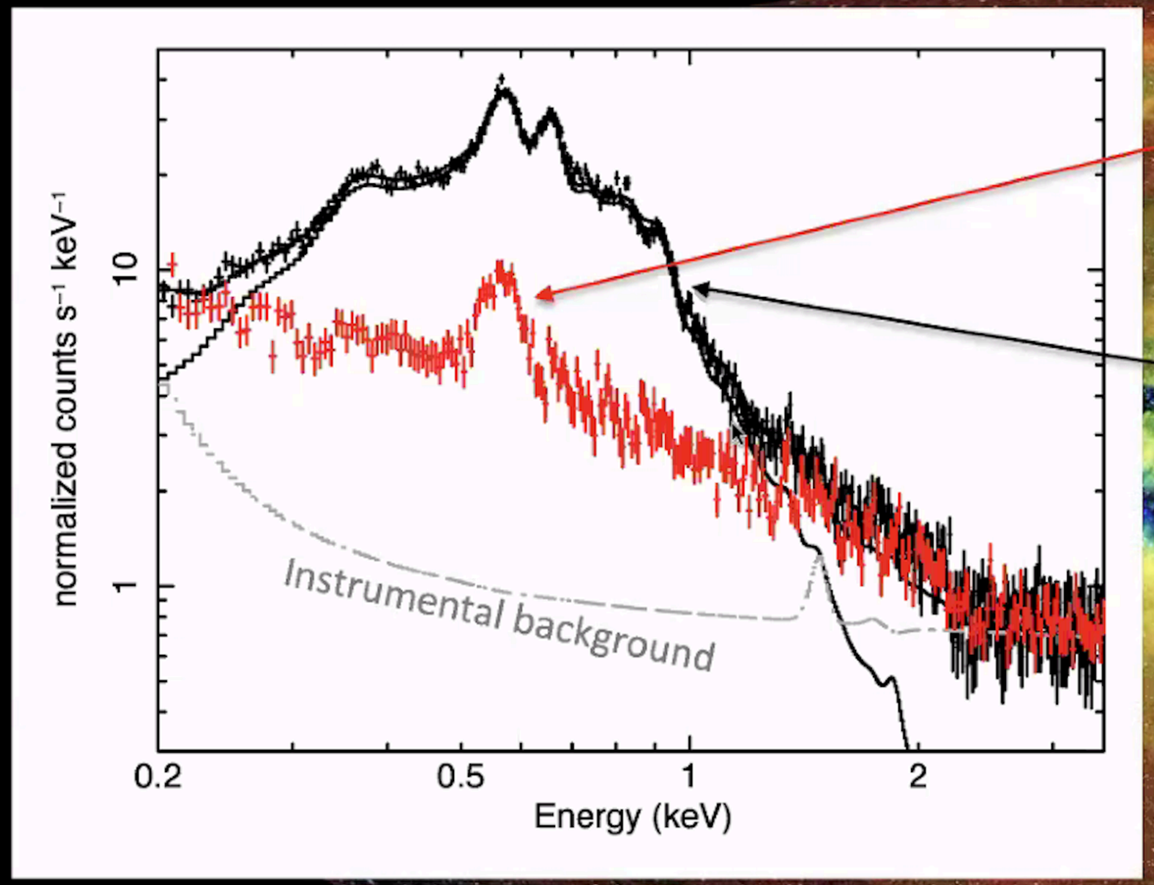
Credit: A. Malyali, A. Rau, Z. Liu, I. Grotova

Nuclear Transients from eRASS2 to eRASS4
(566 objects)

- Dozens of TDE candidates
(Liu et al 2022, Malyali et al 2021, Malyali et al 2022, Homan et al 2023, Krumpe et al, Malyali et al, Grotova et al)
- Increased discovery rate of X-ray bright TDEs by ~order of magnitude-
- The majority (~70-90 %) show no transient optical emission (in ~3 years preceding and during the X-ray detections)
- Optical TDE classification != X-ray TDE classification
- For the synergy to work you need to have as simultaneous observations!

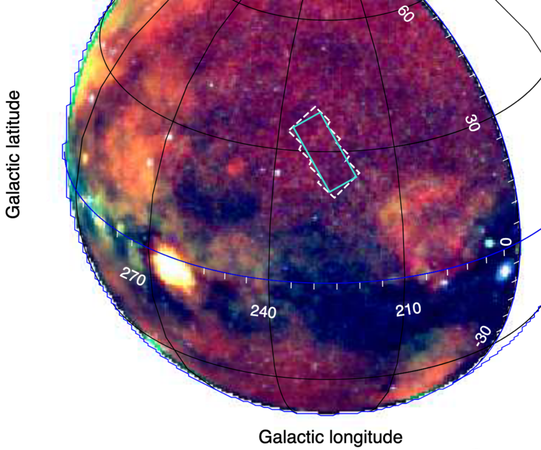


Toward a detailed physical model of the Milky Way CGM



G. Ponti, X. Zheng, N. Locatelli, M. Freyberg

Milky Way CGM spectrum in eFEDS



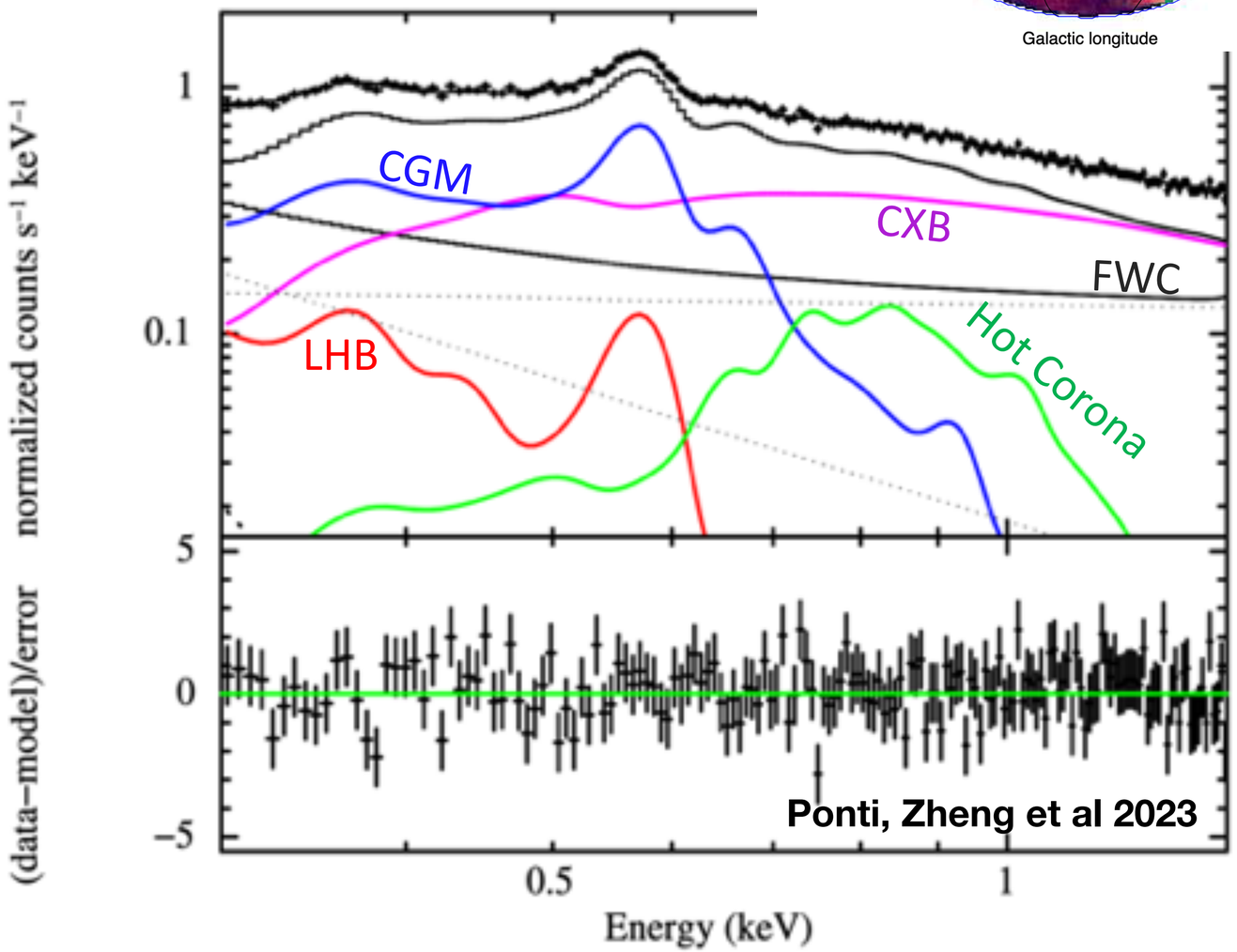
1) Cosmic X-ray background (CXB)

2) Local Hot Bubble (LHB)
kT~0.1 keV

3) Circum-Galactic medium (halo component)
kT = 0.154 ± 0.004 keV
Abun = 0.060 ± 0.003 Solar
Abun Systematics uncert. From CXB shape: 0.05-0.09

4) The Galactic hot corona (NLTE model)
kT>0.4 keV

5) Instrumental background (FWC)



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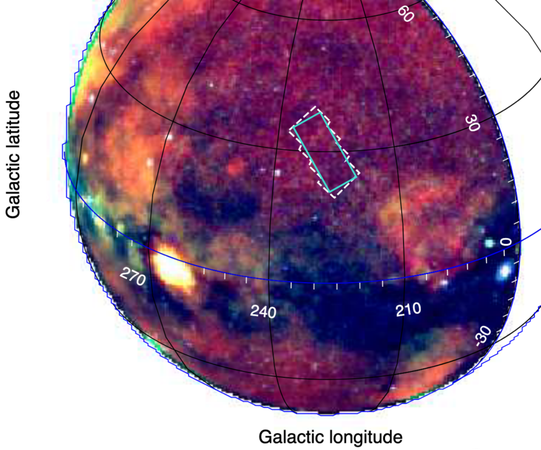

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kT~0.1 keV

Synergy with UVEX: better measure of temperature for LHB (about LBH: Yeung et al submitted)

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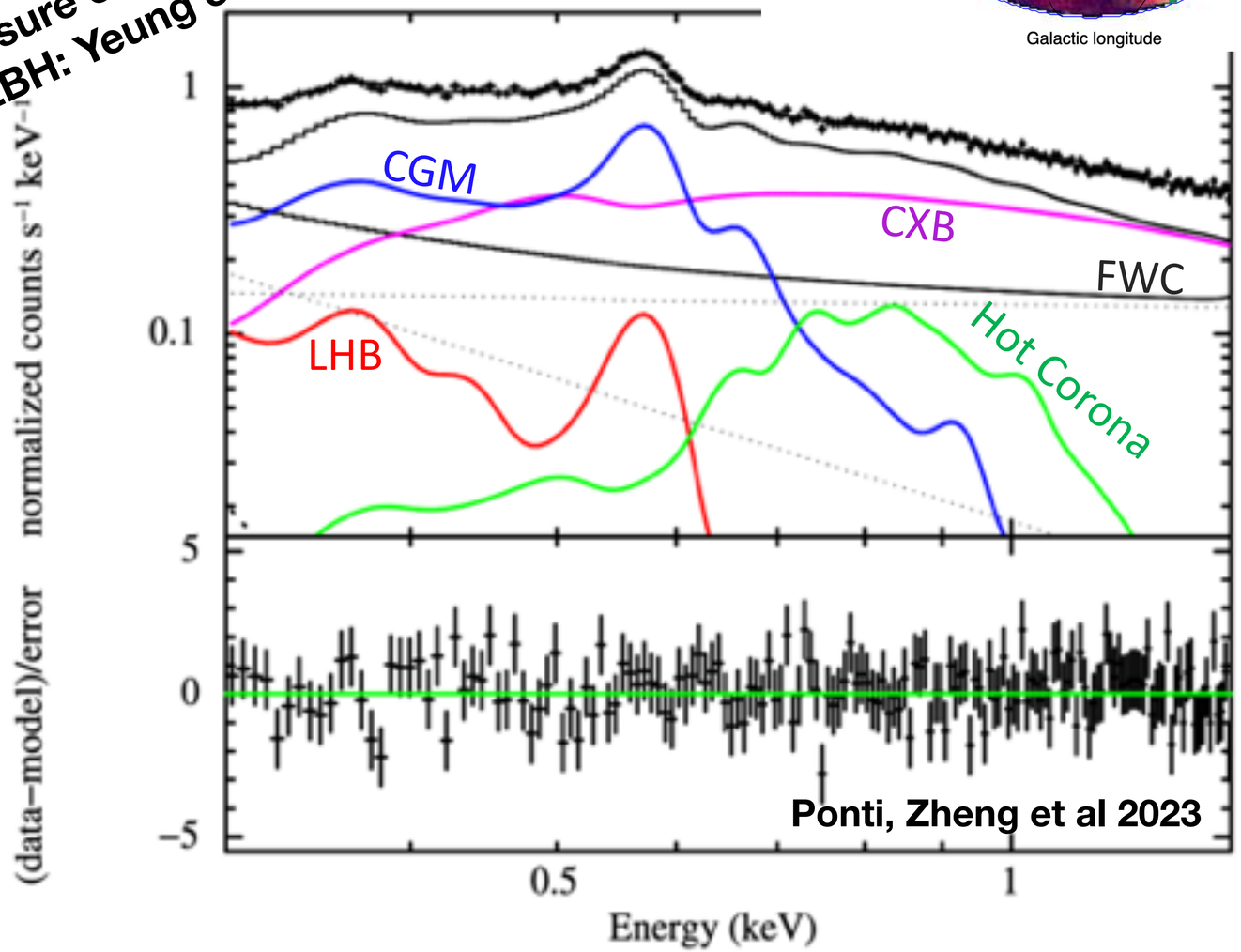
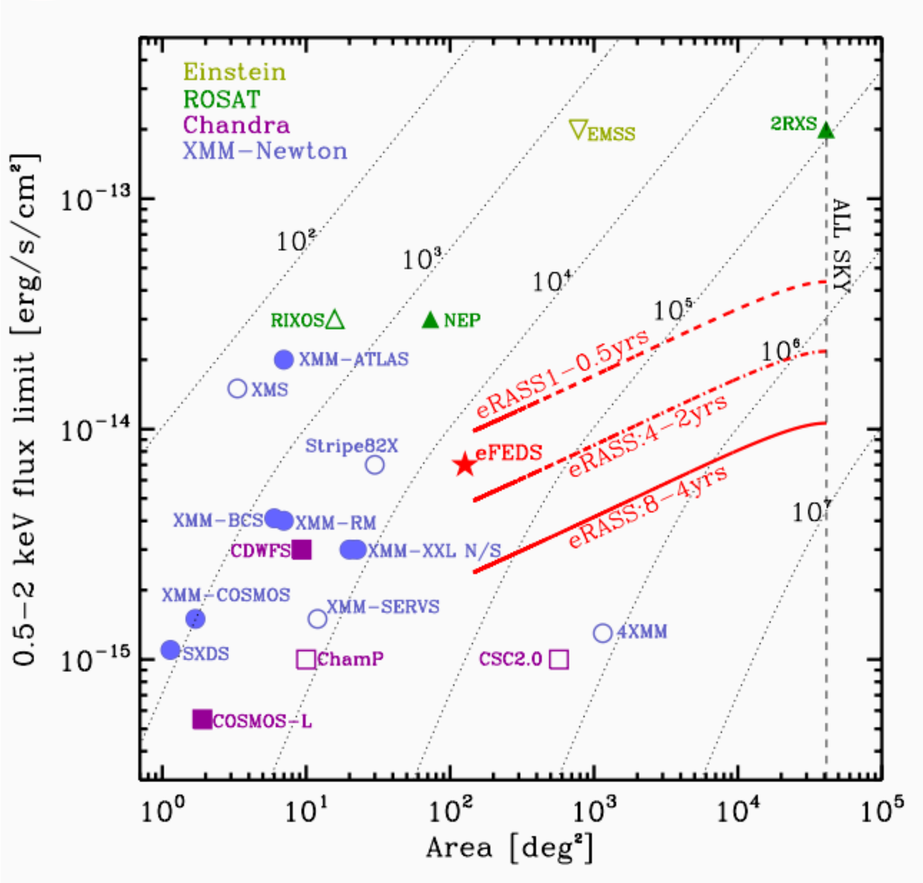
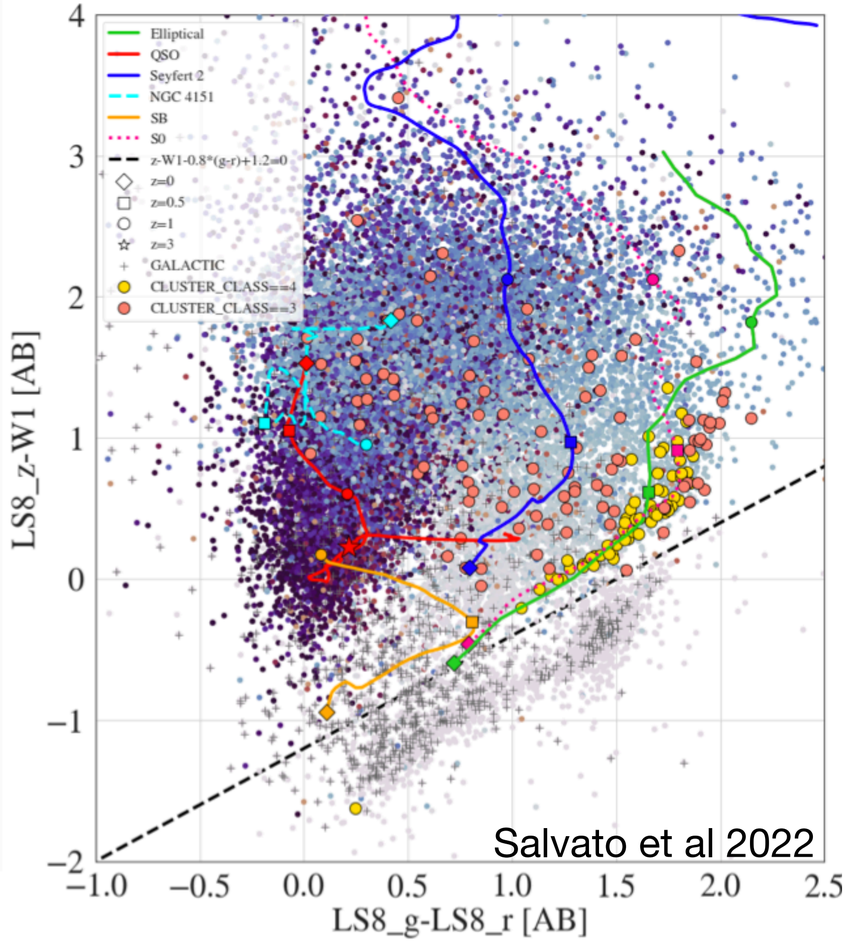
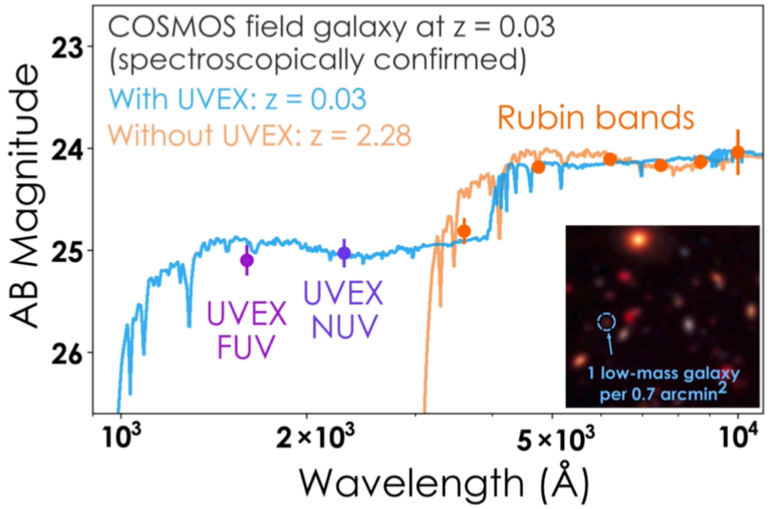


AGN studies



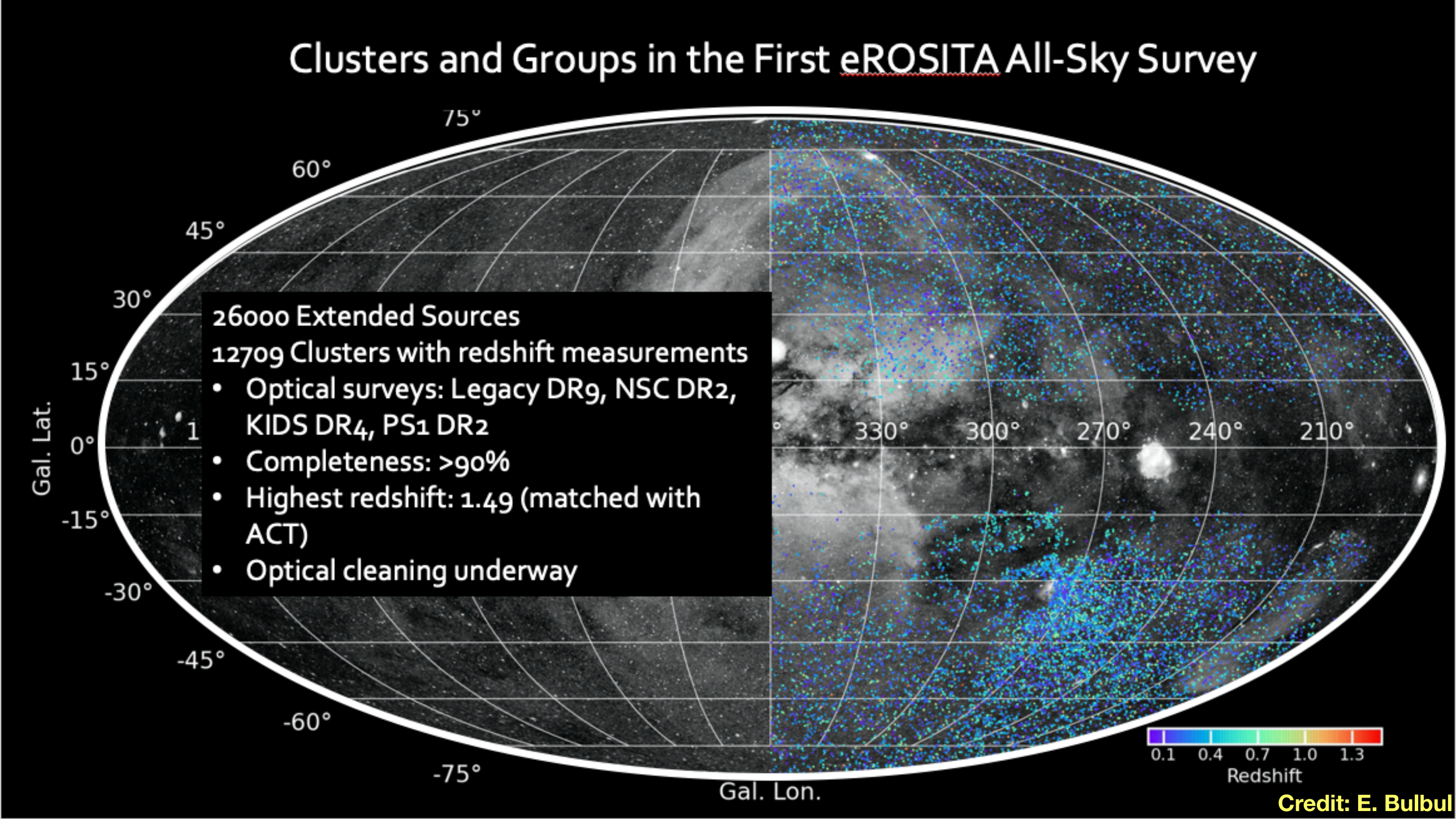




Synergy with UVEX:

Better understanding local AGN (separation Host/AGN emission)
Better UV SED for templates

Clusters and Groups in the First eROSITA All-Sky Survey



Credit: E. Bulbul

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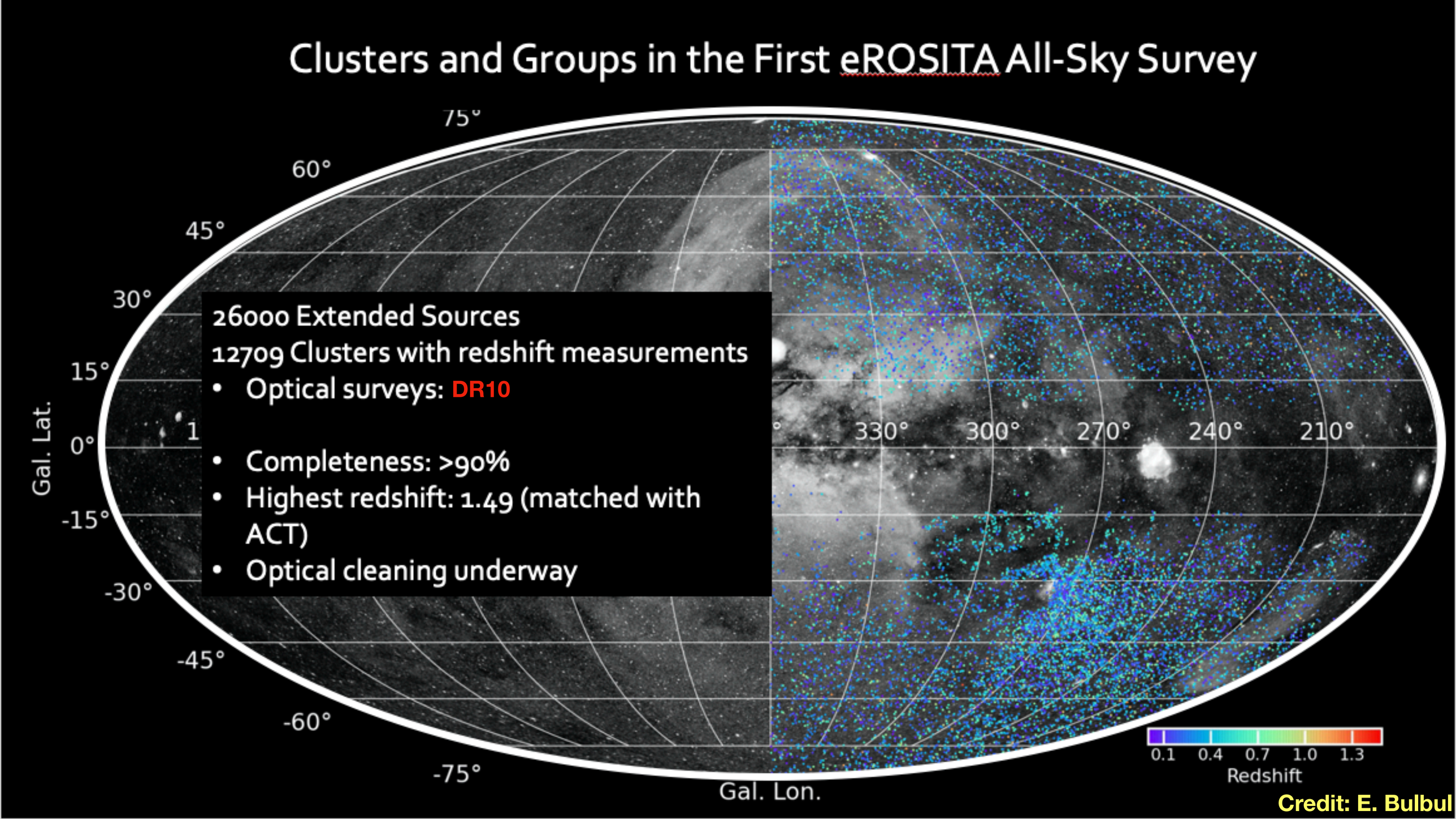
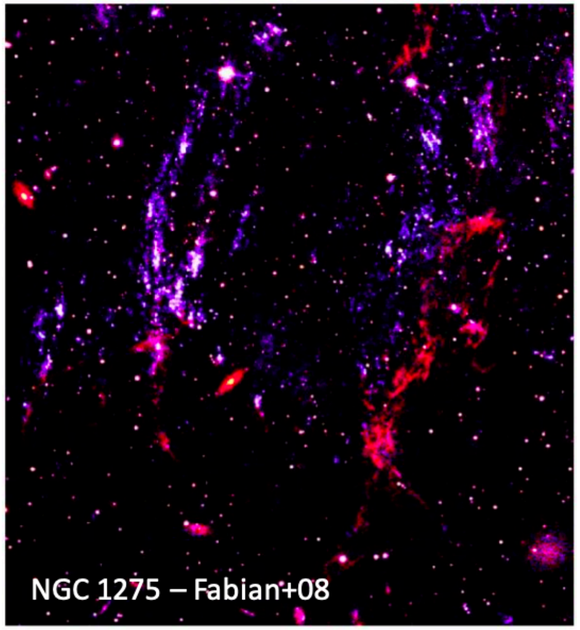
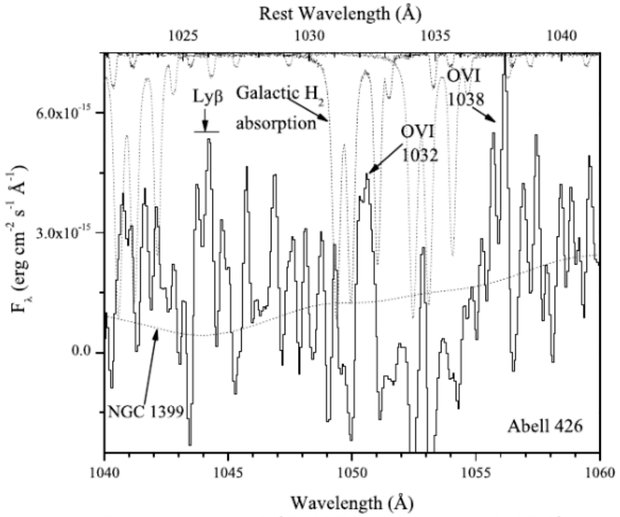


Credit: E. Bulbul

Ultraviolet observations of clusters of galaxies



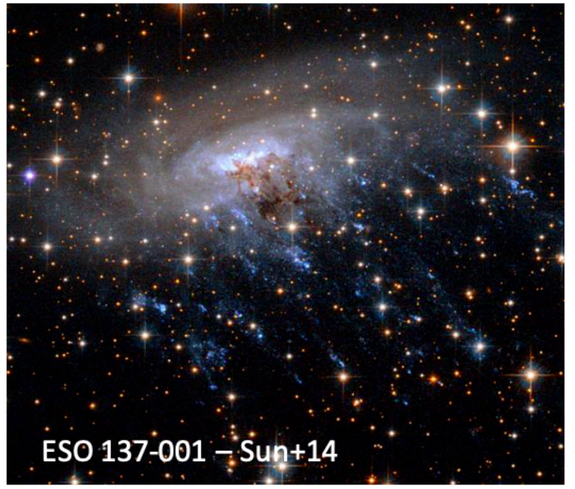
Many BCGs show evidence of star formation (O'Dea+08), particular in cool core clusters. UV measurements of SF are invaluable for understanding how this occurs (Donahue+15), and for understanding how this connects to AGN feedback. Is it due to triggering from AGN mechanical uplift (McNamara+16), or from chaotic cold accretion (Gaspari+13)?



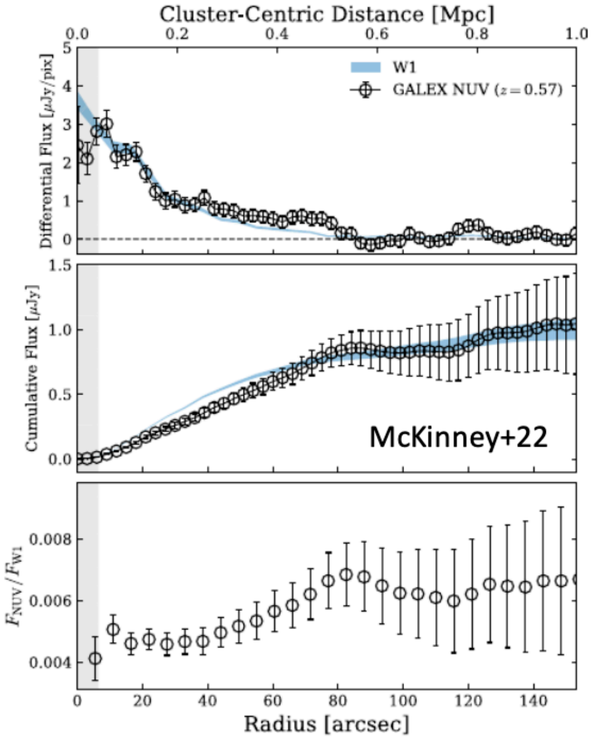
Bregman+06 (FUSE spectrum A426)

UV emission lines (e.g. O VI) are sensitive to warm gas in clusters – can be used to constrain cooling and feedback in a cool core around BCG (above), or search for warm filaments surrounding clusters (Bertone+10), with sufficient sensitivity.

Absorption UV spectroscopy of background QSOs also powerful way to probe previously undetected warm gas in filaments and cluster outskirts (see e.g. Tripp+08).



Ram pressure stripping can be studied in "jellyfish galaxies" passing through the intracluster medium. These contain triggered star formation, seen in the UV, and sometimes also seen in stripped tails (see e.g. Smith+10, Boselli+22).



The effect of environment on star formation and galaxy evolution is still an important topic. UV data are very useful when comparing obscured vs unobscured (e.g. above) star formation rates.

Credit: Jeremy Sanders

SUMMARY

eROSITA on SRG has been operating for more than 2 years and
4.4 all-sky surveys are completed. In safe mode since 26.02.

Thanks to its GRASP, stable background, and observing cadence,
eROSITA opens new parameter space for X-ray astronomy across different source types. All would benefit of UVEX observations.

The all-sky surveys represent a legacy that will remain unsurpassed for years.

UVEX observations of eROSITA sources woul help progressing our understanding of stellar evolution, SFH, AGN evolution, cluster cosmology etc.

By the time UVEX will fly, eROSITA will be public.
(BTW, we are working on the data release of eRASS1!)

Optical spectroscopy will be also avaialble,
thanks to the SDSS-V and 4MOST follow-up programs.